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SPECIFIC GRAVITY-STRENGTH RELATIONS FOR WOOD

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UNITED STATES DEPARTMENT OF AGRICULTURE
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SPECIFIC GRAVITY-STRENGTH RELATIONS FOR WOOD[1]

Studies at the Forest Products Laboratory have shown that the specific gravity of wood substance is nearly the same for all species, and has a value of about 1.5. Since the bulk specific gravity of wood is less than unity for most species, it is evident that a considerable portion of the volume of a piece of wood is occupied by the various cell cavities and pores. For these reasons, the specific gravity of oven-dry wood is an excellent index of the amount of wood substance present, and hence of the strength properties.

The relation of specific gravity to the mechanical properties of wood may be considered from the standpoint of (1) differences between species, and (2) differences between pieces of the same species. Considering different species, the general relation of specific gravity to strength is illustrated by two widely different woods, mastic, a dense Florida species, and balsa, a very light Central American species. Endwise compression tests on green material gave the results of table 1, which show that mastic had nine times the average specific gravity of balsa, and was also nine times as high in crushing strength along the grain. Weight for weight the endwise crushing strengths of these diverse species are substantially equal.

Table 1.--A comparison of the specific gravities and the strength values of two widely different woods in the green condition

Species of wood	Specific gravity based on weight and volume of wood when oven dry	Crushing strength parallel to grain	Specific strength
	1	2	3
		Pounds per square inch	(Col. 2 ÷ Col. 1)
Mastic	1.03	5,880	5,710
Balsa	.11	644	5,850

[1]This mimeograph is one of a series of progress reports issued by the Forest Products Laboratory to aid the Nation's defense effort. Results here reported are preliminary and may be revised as additional data become available.

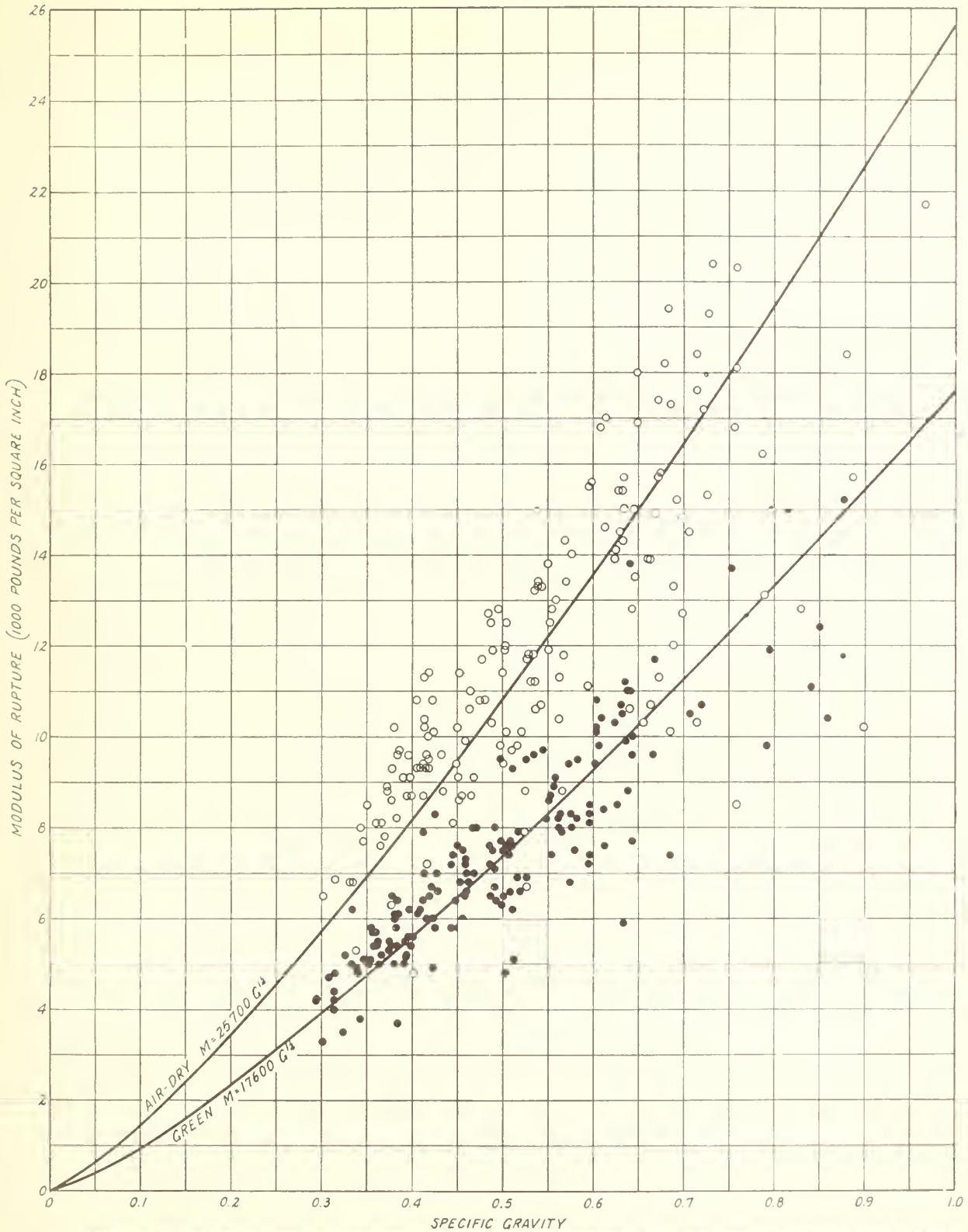
Some properties increase directly with increase in specific gravity while others increase more rapidly. Crushing strength parallel to grain and shrinkage are examples of properties that vary directly with the specific gravity. Modulus of rupture, on the other hand, varies from one species to another as the 1-1/4 power of the specific gravity. Other properties are related to specific gravity by equations of still higher powers; for instance, the exponent of specific gravity for the variation in hardness is 2-1/4. It is evident, therefore, that small differences in specific gravity may result in large differences in certain strength properties.

Specific gravity affords an index of strength also for different pieces of the same species. In fact, the relationship is closer than that between the averages of different species. Furthermore, the curve representing the relationship of pieces within a species is usually of a slightly higher power than that representing the average values for different species. (See accompanying figures).

Some species of wood contain relatively large amounts of resins, gums, and extractives, which, of course, add to the weight but do not contribute to the strength as would a like amount of wood substance. Furthermore, the different species of wood vary somewhat in the structural arrangement of the fibers. For these reasons it is apparent that two species which may be identical in specific gravity may exhibit different average strength characteristics. This fact is illustrated by the scattering of points in the accompanying figure showing the relation betweem modulus of rupture and specific gravity. Hence the specific gravity relationship should be taken as a general trend rather than a perfectly uniform law. A departure from the general curve that applies to most species usually indicates some exceptional characteristic of a species, which may make it particularly desirable for certain use requirements. (The term extractives is used for the compounds that can be removed from the wood of some species by passing cold or hot water, alcohol, or other solvent through it when it is in the form of sawdust. Extractives may be referred to in terms of the solvent used, such as hot-water extractives, for example.)

Minimum Specific Gravity Requirement

The minimum strength values that may be expected from random stock of any species may be materially raised by eliminating a relatively small portion of the material. This is accomplished by fixing a minimum specific gravity requirement (table 2) as one of the specifications for aircraft wood, thus rejecting light-weight stock. The inspection can usually be made satisfactorily by visual examination, but in certain cases it may be desirable or even necessary to resort to actual specific gravity determinations. Such determinations made from time to time are of value to aircraft inspectors in familiarizing them with the relation between appearance and specific gravity.



The relation between bending strength and specific gravity for 115 hardwoods and 48 softwoods. Each point represents the average of a number of tests, up to several hundred for the more important species, on small, clear, straight-grained specimens. The specific gravity values are calculated from the weight of the wood when oven dry and its volume at test

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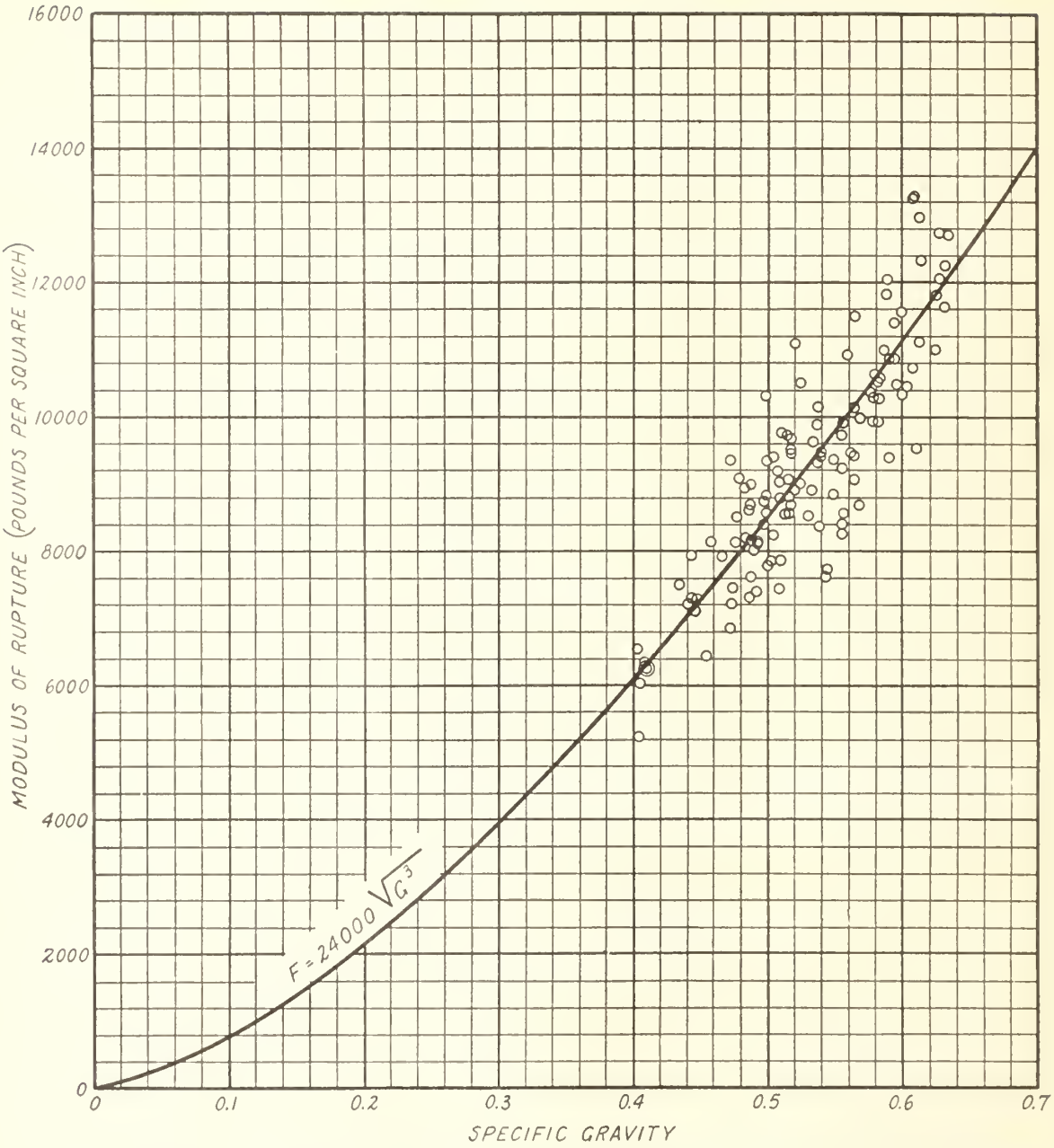

The relation of modulus of rupture to specific gravity for small, clear specimens of white ash tested in a green condition; the specific gravity values are based on the weight of the wood when oven dry and its volume when green

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While no maximum specific gravity limitations are necessary, it is worthy of note that greater uniformity of weight and strength can be obtained by removing the exceptionally dense stock.

Table 2.--Minimum acceptable specific gravity values for aircraft woods

	Specific gravity (based on volume and weight when oven-dry)
HARDWOODS	
Ash, black (Fraxinus nigra)	0.48
Ash, commercial white (Fraxinus sp.)	.56
Basswood, American (Tilia glabra)	.36
Beech, American (Fagus grandifolia)	.60
Birch (Betula sp.)	.58
Cherry, black (Prunus serotina)	.48
Cottonwood, eastern (Populus deltoides)	.39
Elm, rock (Ulmus thomasii)	.60
Hickory (true hickories) (Hicoria sp.)	.71
Khaya (Khaya sp.) ("African mahogany")	.42
Mahogany, true (Swietenia sp.)	.46
Maple, sugar (Acer saccharum)	.60
Oak, commercial white and red (Quercus sp.)	.62
Sweetgum (Liquidambar styraciflua)	.48
Walnut, black (Juglans nigra)	.52
Yellowpoplar (Liriodendron tulipifera)	.38
CONIFERS	
Baldcypress (Taxodium distichum)	.43
Douglas-fir (Pseudotsuga taxifolia)	.45
Incense-cedar, California (Libocedrus decurrens)	.32
Pine, red (Pinus resinosa)	.46
Pine, sugar (Pinus lambertiana)	.34
Pine, eastern white (Pinus strobus)	.34
Pine, western white (Pinus monticola)	.38
Redcedar, western (Thuja plicata)	.31
Spruce (Picea sp.)	.36
White-cedar, Port Orford (Chamaecyparis lawsoniana)	.40
White-cedar, northern (Thuja occidentalis)	.29